National monitoring of Ascaris suum related liver pathologies in English abattoirs: A time-series analysis, 2005-2010

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National monitoring of *Ascaris suum* related liver pathologies in English abattoirs: a time-series analysis, 2005-2010.

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1 Abstract

Ascaris suum the most important internal parasite in farmed pigs world-wide. In England, the BPEX Pig Health Scheme (BPHS) monitors the prevalence of ascariosis in slaughtered finished pigs by identifying milk spots – the healing lesions caused by *Ascaris suum* larvae migration through the liver. This study investigates the trend of milk spot lesions from July 2005 to December 2010 to identify the progress made by the industry in controlling this parasitic disease. For visual explorations, the monthly prevalence for milk spots was modelled using "STL", a seasonal-trend decomposition method based on locally-weighted regression. Random effects binomial modelling accounting for clustering at batch level was used to test the significance of the trend and seasonality. Additionally, the differences in the milk spot prevalence trends for BPHS members (those that joined the scheme) and non-members were investigated and tested. A mean of 12,442 pigs was assessed per month (in 290 batches) across 12 pig abattoirs over the study period, from which a monthly mean of 7,102 pigs (159 batches) came from BPHS members. A mild overall decrease in prevalence of milk spots over the monitored period was identified as well as a seasonal variation which showed peaks in summer and at the

2

beginning of autumn. BPHS members maintained a lower prevalence than non-members. The results from this work illustrate ascariosis as a persistent problem in current farm production.

Key words: *Ascaris suum*; pig, trend, seasonality, milk spots

2 Introduction

Ascariosis is considered the most important internal macro-parasitism present in farmed pigs worldwide (Stewart and Hoyt, 2006) and its control is advocated for several reasons including (1) farm economic losses attributed to depressed feed conversion efficiency (Stewart and Hale, 1988), (2) abattoir operator losses due to offal condemnations (Brown et al., 2007), (3) interference with post-vaccination immunity levels against *Mycoplasma hyopneumoniae* (Steenhard et al., 2009), and (4) a potential contribution to the persistence of *Salmonella* in the intestine – as suggested by the association between these bacteria and the hepatic lesions caused by the parasite (van der Wolf et al., 2001; Smith et al., 2011).

3

Milk spot liver, also known as white spots, refers to the whitish healing foci occurring in the liver stroma associated with the migrating *Ascaris suum* larvae (Stalker and Hayes, 2007). The presence of milk spots has been used to monitor herd prevalence of ascariosis and to investigate its epidemiology (Roneus, 1966; Bernardo et al., 1990; Goodall et al., 1991; Sanchez-Vazquez et al., 2010; Boes et al., 2010). Since 2005, the BPEX Pig Health Scheme (BPHS) has monitored the prevalence of milk spot liver in pigs slaughtered in the main pig abattoirs in England. On a regular basis, swine veterinarians carry out detailed post-mortem examinations in parallel to the routine official food-safety meat inspections. The scheme feeds back benchmarked results from abattoir inspections to the participating producers (i.e. those paying a fee to be part of the scheme) with the purpose of providing motivating strategies to reduce the parasite’s prevalence. The inspections however, include all the batches submitted to the abattoir on the assessment days regardless of their BPHS membership status.

Understanding the temporal patterns of a disease is an essential step in learning about its epidemiology. *A. suum* development is prone to seasonal fluctuations subsequently influencing the within-year prevalence distribution of milk spots (Roneus, 1966; Stevenson, 1979; Wagner and Polley, 1999; Sanchez-Vazquez et al., 2010). Time-series analyses aim to provide a concise description of data correlated

 4

through time (Diggle, 1990), usually by exploring both time trend and seasonal pattern. Through a time-series analyses, Goodall (1991) explored the prevalence of *A. suum* infestations using abattoir liver condemnation data, but no recent investigations of the temporal distribution of this parasite prevalence has been published. In the current British industry, outdoor farming and bedded flooring are common, both potential determinants for the presence of *A. suum* (Roepstorff and Nansen, 1994; Dangolla et al., 1996; Sanchez-Vazquez et al., 2010); whilst on the other hand, efficient antihelminthic protocols are expected to be in use. In this respect BPHS, with over five years of consistent monitoring in English abattoirs, offers a unique opportunity to explore the temporal patterns of the prevalence of milk spots as a proxy to reflect the underlying prevalence of *A. suum*.

This paper presents a time-series analysis to explore the prevalence of milk spot livers, as reported by BPHS from July 2005 to December 2010. This work's main objective is to provide an up to date seasonal pattern on the prevalence of milk spots and to identify the progress made by the industry in controlling this parasitic disease, particularly by comparing members versus non-members. Furthermore, the intention of this study is to reflect the relevance of ascariosis in the English system by reporting the prevalence of its lesion, which might

5

trigger the development/review of new control strategies of this parasite.

3 Material and methods

3.1 Data source and study population

BPHS has monitored the prevalence of milk spot livers across the largest pig abattoirs in England since July 2005. Pig veterinarians trained in this method of assessment at the abattoir inspection line assess every second pig in a batch (up to fifty pigs assessed) for gross pathology. BPHS organises training and refresher days for the veterinarians and conducts internal comparisons on the same pigs assessed by different veterinarians, aiming to maintain assessor consistency over time. This study used the combined BPHS records, for both members and non-members, available from the 12 abattoirs that participated in BPHS from July 2005 to December 2010. The abattoirs are geographically widely distributed across England (see Figure 1). A total of 821,159 pigs (19,160 batches) submitted from 1,517 herds were assessed over the period studied.

3.2 Time-series modelling

3.2.1 The strategy

The time-series analyses were carried out in two steps. Firstly, visual analytics were used to graphically investigate and describe the trend

6

and the seasonal pattern. Secondly, the trend, the effects of season (month) and BPHS membership were statistically tested.

3.2.2 Time series visual explorations

For exploratory purposes, time-series “fractions” were composed of monthly prevalence estimates, computed as the number of pigs affected with milk spots, divided by the number of pigs assessed. The seasonal cycle was studied yearly (12 month). This exploratory process was carried out using a nonparametric procedure for seasonal-trend decomposition of time-series based on locally-weighted regression (loess), known as “STL” (Cleveland et al., 1990). This method is a filtering procedure for decomposing a time-series into additive components of variation (trend, seasonal and the remainder) by the application of loess smoothing models (Cleveland et al., 1990). STL has good visualization capabilities which make it a useful tool for visual analytics (Hafen et al., 2009). The adequacy of the model fit was assessed by graphical diagnostic methods (Cleveland et al., 1990). Using STL, the overall trend of both members’ and non-members’ combined data and the seasonal pattern was explored. Additionally, the STL trend for the members and non-members was explored separately.

3.2.3 Statistical testing

7

Batch prevalence was modelled against time in monthly intervals. The seasonal effect of the month (i.e. January, February, and so on) and the effect of membership status (member versus non-member) were tested by being added as model covariates. Four models were attempted in these analyses: (1) a simple binomial model, (2) a binomial model with random effects to allow for clustering at batch level, (3) a zero-inflated binomial model, and (4) a beta-binomial model allowing for clustering at batch level. These two latter models were explored due to the high relative number of batches with zero prevalence of milk spots. The measure of the goodness of fit Akaike's Information Criterion (AIC) was used for comparison among the different model distributions and also to compare nested models through a stepwise covariates selection process. Wald test was used to examine the significance level (p value <0.05) of the variables retained in the final model, particularly for that with multiple classes (i.e. month). All analyses and graphs were performed using the R statistical software environment (R Development Core Team, 2009) using libraries stats, epicalc, lme4 and VGAM.

4 Results

The mean number of pigs assessed per month was 12,442 pigs (standard deviation (SD) 2,527), with a mean of 290 batches (SD 60). Of those, the mean number of pigs from BPHS members was 7,102

8

pigs (SD 1,691) with a mean of 159 batches (SD 39). A total of 34,168 pigs (from 5,370 batches) were affected with milk spots livers which represent 4.2% of the total pigs inspected (3.7% of the members and 4.8% of non-members).

4.1 Results from the exploratory analyses

The STL trend identified (Figure 2, graph (a)) an initial decline in the prevalence of milk spot liver, particularly between 2006 and 2008. There is change in the trend, however, with the prevalence of the lesions increasing slightly over 2010. The STL seasonal component observed (Figure 2, graph (b)) shows an increase of milk spot lesions at the end of the summer and beginning of autumn, and a decline in winter and spring. Scheme members and non-members follow two distinctive trends (Figure 2, graphs (c) and (d) respectively). It is observed that the trend for the members levels out following an initial bump, and thereafter maintains a prevalence of under 4% from mid 2007; while the non-members, with higher initial prevalence than the members, had a marked decrease until 2009 at which time the prevalence started to increase.

4.2 Results from the statistical testing

The random effects binomial model allowing for clustering at batch level provided the best goodness of fit, AIC 33,750. The AIC values for

9

the simple binomial, the zero-inflated binomial and the beta-binomial models were 163,567, 97,621 and 50,398 respectively. The results for the final multivariable random effects binomial model are presented in Table 1. Overall, there is a significant trend toward reduction (estimated coefficient -0.026, p-value <0.001). September and October were the two months which had the highest (significant) prevalence compared with March, the month with the lowest prevalence (and taken as the baseline). There are significant differences between members and non-members, with non-members having a higher prevalence of milk spots over the period studied.

5 Discussion

This paper investigates and presents the prevalence of milk spot liver in English pigs from July 2005 to December 2010 with focus on time trend and seasonality, in an attempt to reflect the temporal pattern of *A. suum.* This is facilitated by the exceptionally large sample size of quality abattoir inspection data sourced from the BPEX Pig Health Scheme.

The overall trend shows a general reduction over the monitoring period (2005-2010). This trend is, however, composed of both members' and non-members' results which behave as two different populations with significant differences being found between them. The members had, since the beginning of the BPHS monitoring, a lower prevalence (compared to non-members) which was maintained across the monitoring period. Despite the members and their vets receiving feed-back from the abattoir results, only a mild appreciable reduction in prevalence (after an initial worsening) was evident. Perhaps this level reflects an “as good as it gets” position on the control of this parasite with current strategies in the English production system. In a previous time series-analyses carried out in Northern Ireland (Goodall et al., 1991) where slatted floor systems are widely used, an increasing trend was found, reporting a 9% prevalence of pigs affected with liver lesions in 1989 (the end of the study period), much higher than the level observed in this study.

The prevalence of milk spot livers in pigs submitted by non-members decreased considerably between 2005 and 2009. Although the BPHS non-members did not receive feed-back on the prevalence of milk spots liver in their herds, vet practices might recommend similar worming and control protocols to all their clients. The information from BPHS members could have been used indirectly in this way, to influence non-members’ control strategies. Additionally, some of the larger integrated pig businesses only have a few units registered as BPHS members but they implement a worming strategy which they roll out across all finishing units. Overall, the difference in prevalence observed between members and non-members might reflect different attitudes in the control of parasitic diseases – thus, those producers not willing to join the health scheme might also be less prone to implement efficient worming control strategies.

The STL results show the prevalence of milk spot livers increasing at the end of summer/ beginning of autumn and declining in winter/spring. This pattern is similar to that previously reported (Goodall et al., 1991) and is explained by the development of *A. suum* eggs associated with warmer temperatures (Wagner and Polley, 1999). Such a clear seasonal pattern serves to illustrate (overall) insufficient control of the parasite.

BPHS abattoir records have been considered to provide reliable trends (Stark and Nevel, 2009) and this system of detailed post-mortem inspection is presumed to have good sensitivity and specificity. A similar inspection system, which also focused on a limited number of organs and pigs, was found to have good classification characteristics (Enoe et al., 2003). The presence of operator bias affecting the gross pathology classification over time cannot be ruled out; this is unlikely to happen, however, as the lesion definition has not changed since BPHS started. On the whole, any imperfection in the scoring in this investigation could be considered randomly distributed over time. The study population was defined as those pigs assessed over time by BPHS. We could, however, confidently extrapolate our findings to the English commercial (professional) pig finishing units, as the BPHS assessments are likely to be highly representative of the monthly cross-sectional disease prevalence occurring in these pig units.

6 Conclusion

This study detects a mild reduction in the prevalence of milk spots in English farmed finishing pigs over a monitoring period from 2005 to 2010. Producer members of BPHS have maintained lower prevalence levels of milk spots than non-members. This study shows that ascariosis is a persistent problem in English farmed pigs and provides an example of the utility of abattoir health schemes based on detailed post-mortem inspection as a large-scale health monitoring tool.

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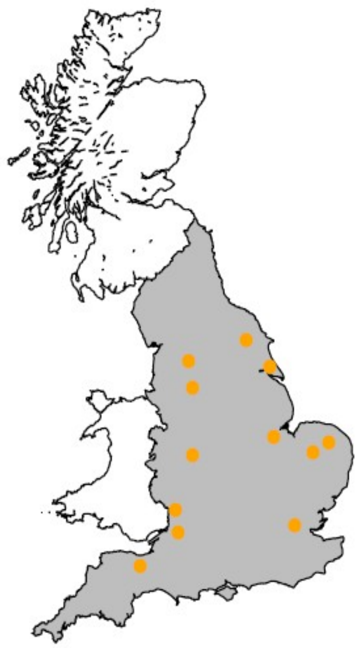

Figure 1. Map of Great Britain showing England shaded and representing with dots the location of the 12 abattoirs included in the study.

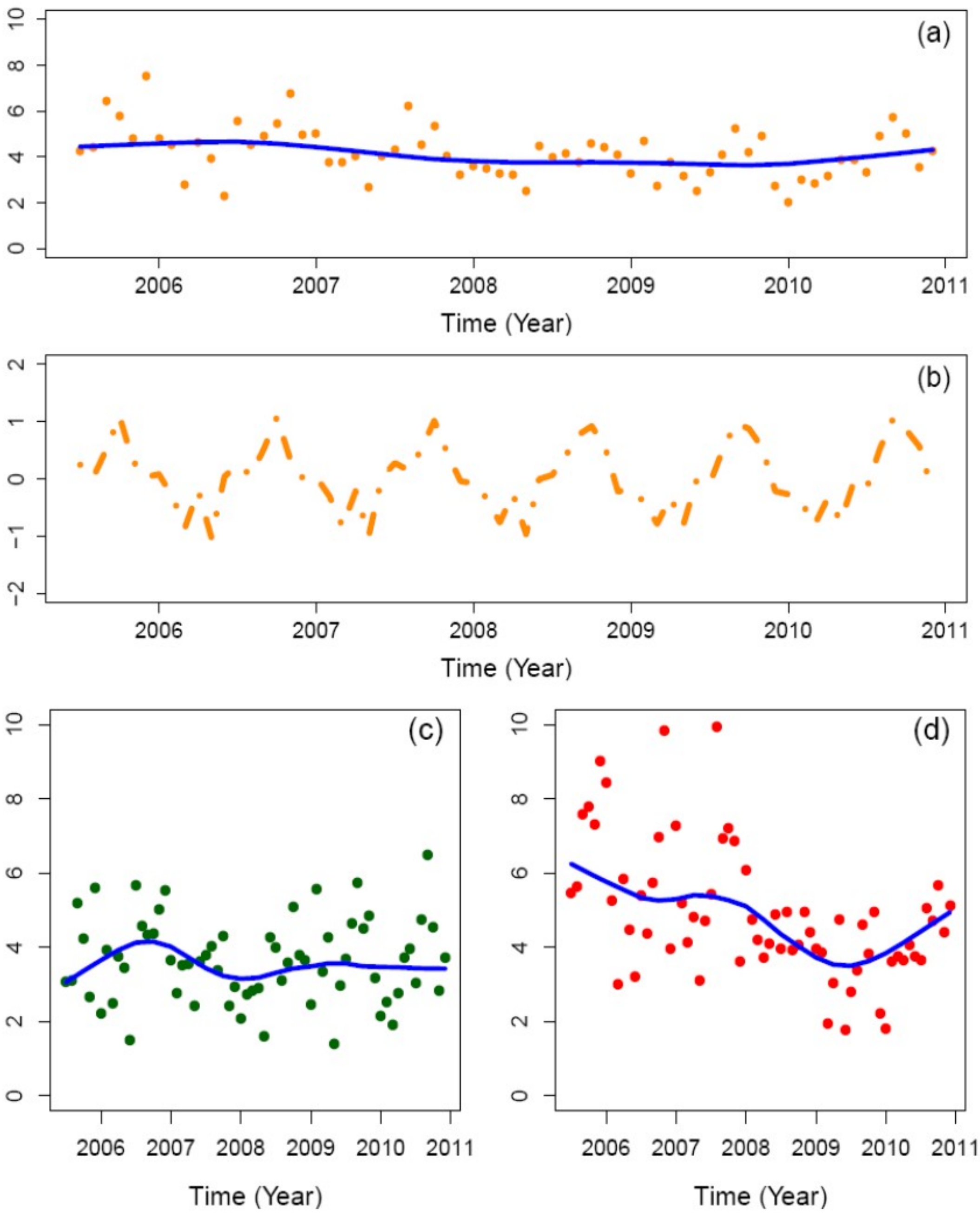

Figure 2. Trend and seasonality of the prevalence of pigs affected with milk spots in 12 English abattoirs (2005-2010), STL method. In the graph (a) the dots represent the monthly prevalence for all BPHS assessments (combining results for members and non-members) and the line is the STL fitted trend. The graph (b) presents the STL seasonal pattern per 12 months for all BPHS members. In graph (c) the dots represent the monthly prevalence for BPHS members and the line their STL fitted trend. In graph (d) the dots represent the monthly prevalence for BPHS non-members and the line their STL fitted trend.

The units in the vertical axis represent the percentages of pigs affected with milk spot livers.

Table 1. Estimated coefficients for the covariates in the multivariable random effects binomial model for the prevalence of milk spot livers in finishing pigs slaughtered in English abattoirs, 2005-2010. N=19,160 batches.

Farm variable	Level	Estimate	Standard error	P-value
Trend	Monthly	-0.026	0.002	<0.001
Month	July	-0.132	0.151	0.383
	August	0.019	0.153	0.902
	September	0.528	0.149	<0.001
	October	0.751	0.144	<0.001
	November	0.151	0.149	0.313
	December	-0.052	0.165	0.75
	January	0.31	0.154	0.045
	February	0.302	0.157	0.055
	March	0	-	-
	April	0.128	0.154	0.29
	May	0.026	0.158	0.577
	June	0.063	0.163	0.804
Being a BPHS member	Non-member	0.425	0.059	<0.001
	Member	0	-	-